



BASELINE RISK ASSESSMENT ADDENDUM for

Appendix A of the Ballard Mine RI/FS Report
February 2015
FINAL



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**BALLARD MINE
REMEDIAL INVESTIGATION AND FEASIBILITY STUDY
REMEDIAL INVESTIGATION REPORT -
BASELINE RISK ASSESSMENT
ADDENDUM**

FINAL

February 2015

Prepared by

MWH

Prepared for:

P4 Production, LLC

TABLE OF CONTENTS

1.0 Introduction	1-1
1.1 Purpose, Objectives and Scope	1-1
2.0 Risk Assessment Methodology.....	2-1
2.1 Conceptual Site Model.....	2-1
2.1.1 Exposure Media.....	2-1
2.1.2 Receptors and Exposure Pathways.....	2-1
2.1.3 Exposure Assumptions	2-2
2.2 Risk Characterization	2-3
3.0 Summary of Human Health Estimates	3-1
4.0 References	4-1

LIST OF TABLES

A-1	Exposure Parameters Used in the Human Health Radiological Risk Assessment
A-2	Tier I Ballard Mine Radiological Risk Calculations for a Native American
A-3	Tier I Ballard Mine Radiological Risk Calculations for a Seasonal Rancher
A-4	Tier I Ballard Mine Radiological Risk Calculations for a Recreational Hunter
A-5	Tier I Ballard Mine Radiological Risk Calculations for a Recreational Camper/Hiker

LIST OF APPENDICES

Appendix A	Comments and Response to Comments
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ACRONYMS AND ABBREVIATIONS

A/Ts	Agencies and Tribes
BRA	baseline risk assessment
COPC	contaminant of potential concern
CSM	conceptual site model
EPC	exposure point concentration
FS	feasibility study
g	gram
HHERA	human health and ecological risk assessment
HHRA	human health risk assessment
IDEQ	Idaho Department of Environmental Quality
ILCR	incremental lifetime cancer risk
kg	kilogram
L	liter
mg	milligram
MWH	MWH Americas, Inc.
P4	P4 Production, LLC
PEF	particulate emission factor
pCi	picocurie
PRG	preliminary remediation goal
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RME	reasonable maximum exposure
TR	target risk
USEPA	United States Environmental Protection Agency

1.0 INTRODUCTION

This Baseline Risk Assessment Addendum (BRA Addendum) has been prepared to supplement the *Remedial Investigation Report for P4's Ballard Mine – Rev 2 Final (Final Ballard Mine RI Report; MWH, 2014)*. The *Final Ballard Mine RI Report* also includes a *Baseline Risk Assessment Report for the Ballard Mine and Ballard Shop (Ballard Mine BRA Report)* in Appendix A. These documents were prepared by MWH Americas, Inc. (MWH) on behalf of P4 Production, LLC (P4), as part of the comprehensive mine-specific Remedial Investigation/Feasibility Studies (RI/FS) that are being conducted at P4's three historic phosphate mines. The historic mine sites include Ballard, Henry and Enoch Valley mines, collectively known as the "Sites" located in southeast Idaho. This BRA Addendum was prepared at the request of the Agencies and Tribes (A/Ts) to provide additional risk estimates for human receptors potentially exposed to radiological constituents in environmental media at the Ballard Mine that were omitted from the initial *Ballard Mine BRA Report* in Appendix A.

1.1 Purpose, Objectives and Scope

The *Ballard Mine BRA Report* includes an evaluation of potential human health risks for a hypothetical future resident exposed to radiological daughter products of uranium in environmental media at the Ballard Mine. The hypothetical future resident was evaluated as a worst-case analysis of potential human health risks associated with exposures to uranium daughter products. The A/Ts tentatively approved the *Ballard Mine BRA Report* pending an evaluation of potential radiological risks for additional human receptors and land uses. The purpose of this BRA Addendum is to evaluate and document the supplemental radiological risk evaluations for the Ballard Mine. The specific objectives of this BRA Addendum are to summarize (1) the methods and procedures used in the evaluation of potential human health risks associated with radiological constituents at the Ballard Mine, and (2) receptor-specific human health risk estimates associated with potential human exposures to radiological daughter products of uranium.

The scope of this BRA Addendum is limited to the following human receptors: Native American, seasonal rancher, recreational hunter and recreational camper/hiker. These receptors are evaluated herein because chemical risks, but not radiological risks, were evaluated for these receptors in the *Ballard Mine BRA Report*. Consistent with the *Ballard Mine BRA Report*, a recreational fisherman was not evaluated in this BRA Addendum because none of the surface water features on or immediately downgradient of the Ballard Mine support fish. As described in the above paragraph, potential risks associated with a hypothetical future resident already were evaluated in the *Ballard Mine BRA Report* and, therefore, are not presented in this BRA Addendum.

The environmental media evaluated in this BRA Addendum are limited to upland soil and surface water because these are the only media for which uranium was selected as a contaminant of potential concern (COPC). At the request of the A/Ts, potential human health risks associated with exposures of the above receptors to uranium daughter products were evaluated based on concentrations of radium-226 calculated from total uranium concentrations assuming secular equilibrium between uranium-238 and radium-226.

2.0 RISK ASSESSMENT METHODOLOGY

This section describes the procedures used to quantitatively evaluate risks associated with radiological daughter products of uranium at the Ballard Mine.

2.1 Conceptual Site Model

A complete site-specific human health conceptual site model (CSM) for the Ballard Mine was included in the *Final Ballard Mine RI Report*. The exposure media, receptors and exposure pathways that were evaluated herein are summarized below.

2.1.1 Exposure Media

Potentially contaminated media at the Ballard Mine include surface soil, surface water, groundwater, and biota. Field investigation analytical data were summarized and compared to human health screening criteria in the *Final Ballard Mine RI Report* to identify COPCs. The refined human health COPC screening for upland soil and surface water identified uranium as a COPC. As requested by the A/Ts during the development of the Human Health and Ecological Risk Assessment (HHERA) Work Plan (Appendix C of the *Ballard, Henry and Enoch Valley Mines RI/FS Work Plan*; MWH, 2011) and the *Final Ballard Mine RI Report*, potential risks associated with human exposures to radium-226 were evaluated in upland soil and surface water because uranium was selected as a COPC in these media.

2.1.2 Receptors and Exposure Pathways

Receptors exposed to potentially contaminated media at the Ballard Mine include a hypothetical future resident, a Native American, a seasonal rancher, a recreational hunter, and a recreational camper/hiker. Only the hypothetical future resident is evaluated quantitatively for exposure to radium-226 and its decay products in upland soil in the *Ballard Mine BRA Report*. However, now as requested by the A/Ts' in their comments on the Ballard Mine BRA, the Native American, seasonal rancher, recreational hunter, and recreational camper/hiker are evaluated quantitatively for exposure to radium-226 and its decay products in this BRA Addendum.

The exposure pathways quantitatively evaluated for each of these receptors are summarized below.

Native American

- Incidental ingestion of soil
- Inhalation of soil particulates
- External exposure

- Ingestion of culturally significant upland plants
- Ingestion of surface water
- Immersion in surface water
- Ingestion of game

Seasonal Rancher

- Incidental ingestion of soil
- Inhalation of soil particulates
- External exposure
- Ingestion of beef

Recreational Hunter

- Incidental ingestion of soil
- Inhalation of soil particulates
- External exposure
- Ingestion of game

Recreational Camper/Hiker

- Incidental ingestion of soil
- Inhalation of soil particulates
- External exposure

2.1.3 Exposure Assumptions

Exposure assumptions used in this BRA Addendum are presented in Table A-1. The exposure parameters used in this BRA Addendum are consistent with those used in the *Ballard Mine BRA Report*, except for the differences described below.

Exposure Duration for the Recreational Camper/Hiker

The recreational scenario in the Preliminary Remediation Goals (PRGs) Calculator (USEPA, 2014) only includes the adult and child. As a result, no separate youth recreational camper/hiker was evaluated in this BRA Addendum. The adult recreational camper/hiker exposure duration was assumed to be 24 years, which is the sum of adult and youth recreational camper/hiker exposure duration presented in the *Ballard Mine BRA Report*.

Inhalation Rate, Cover Layer Thickness, and Slab Size

The parameters of inhalation rate, cover layer thickness and slab size were not parameters that were used to estimate chemical-related risks in the *Ballard Mine BRA Report*. As a result, default parameters available from the PRG calculator (USEPA, 2014) were used for the inhalation rate

and cover layer thickness. The slab size was conservatively assumed to be 1,000,000 m², which is the available input slab size closest to the Ballard Mine Site area of 412 acres.

Particulate Emission Factor

The PRG Calculator (USEPA, 2014) does not allow for the input of a site-specific particulate emission factor (PEF). As a result, the default value for Boise, Idaho was used because the calculated PEF was close to the PEF used in the *Ballard Mine BRA Report*.

Game Intake Rate for the Native American

The recreational scenario in the PRG Calculator (USEPA, 2014) does not allow for the input of separate child and adult game intake rates. As a result, the game intake rate for a Native American receptor was based on the age-adjusted rate calculated using the adult and child Native American exposure durations and game ingestion rates presented in the *Ballard Mine BRA Report*.

2.2 Risk Characterization

Cumulative incremental lifetime carcinogenic risks (ILCRs) for radium-226 exposures were calculated using exposure point concentrations (EPCs) for radium-226 activity in soil and surface water extrapolated from measured total uranium concentrations in those media and medium-specific PRGs generated using the PRG Calculator website (USEPA, 2014).

$$(1) \quad \text{ILCR (unitless)} = \frac{\text{EPC}}{\text{PRG}} \times \text{TR}$$

Where:

ILCR	= Incremental lifetime carcinogenic risk (unitless)
EPC	= Exposure point concentration (pCi/g or pCi/L)
PRG	= Preliminary remediation goal (pCi/g or pCi/L)
TR	= Target risk (unitless)

Human health risk estimates calculated in the Tier I Human Health Risk Assessment (HHRA) portion of the *Ballard Mine BRA Report*, and in this BRA Addendum, utilized EPCs based on the maximum detected concentration in each exposure medium and reasonable maximum exposure estimates (RME) for media uptake. Based on comments received during the development of the HHRA Work Plan (MWH, 2011), the maximum detected total uranium concentrations in soil and surface water were assumed to be representative of uranium-238 and radium-226 activity concentrations. The Tier I total uranium soil EPC in milligram per kilogram (mg/kg), as presented in the Tier I HHRA portion of the *Ballard Mine BRA Report*, was converted to a radium-226 EPC in picocurie per gram (pCi/g) with a conversion factor of 0.742/2.21 pCi/g/mg/kg. The Tier I dissolved total uranium surface water EPC in mg/L, as presented in the Tier I HHRA portion of the *Ballard Mine BRA Report*, was converted to radium-226 EPCs in

pCi/L with a conversion factor of 336 pCi/L/mg/L. The RME-based exposure estimates used as input to the PRG Calculator are presented in Table A-1 and are equivalent to the exposure parameters used in the *Ballard Mine BRA Report*, except for PRG Calculator-specific differences, as noted in Table A-1 and described in Section 2.1.3.

3.0 SUMMARY OF HUMAN HEALTH ESTIMATES

Tier I human health risks estimated for the:

- Native American (current/future),
- Seasonal rancher (current/future),
- Recreational hunter (current/future), and
- Recreational camper/hiker (current/future)

at the Ballard Mine are presented in **Tables A-2** through **A-5**, and summarized in this section.

Cumulative, Tier I ILCR estimates for the Ballard Mine were compared to USEPA's risk management range of 1×10^{-6} to 1×10^{-4} for carcinogenic risk (USEPA, 1991) and to Idaho Department of Environmental Quality's (IDEQ's) point-of-departure carcinogenic risk criterion of 1×10^{-5} when making risk management recommendations.

Native American - Current/Future

The cumulative, Tier I radiological RME ILCR estimate for a current/future Native American in upland soil and surface water at the Ballard Mine is 1×10^{-2} , as shown in **Table A-2**. The primary contributing exposure pathway to a cumulative Tier I RME ILCR estimate in excess of IDEQ's and USEPA's acceptable risk criteria is the ingestion of culturally significant plants grown in upland soil.

Seasonal Rancher - Current/Future

The cumulative, Tier I radiological RME ILCR estimate for a current/future seasonal rancher in upland soil and surface water at the Ballard Mine is 5×10^{-4} , as shown in **Table A-3**. The primary contributing exposure pathway to a cumulative Tier I RME ILCR estimate in excess of IDEQ's and USEPA's acceptable risk criteria is external exposure to ionizing radiation from soil.

Recreational Hunter - Current/Future

The cumulative, Tier I radiological RME ILCR estimate for a current/future recreational hunter in upland soil and surface water at the Ballard Mine is 2×10^{-4} , as shown in **Table A-4**. The primary contributing exposure pathway to a cumulative Tier I RME ILCR estimate in excess of IDEQ's and USEPA's acceptable risk criteria is external exposure to ionizing radiation from soil.

Recreational Camper/Hiker - Current/Future

The cumulative, Tier I radiological RME ILCR estimate for a current/future recreational camper/hiker in upland soil at the Ballard Mine is 1×10^{-4} , as shown in **Table A-5**. The primary contributing exposure pathway to a cumulative Tier I RME ILCR estimate in excess of IDEQ's acceptable risk criterion is external exposure to ionizing radiation from soil.

Conclusions

Tier I radiological risk estimates for all of the above receptors exceed IDEQ's and USEPA's risk management criteria, with the exception of the Tier I radiological RME ILCR estimate for a current/future recreational camper/hiker which is above the IDEQ risk management criterion, but does not exceed the upper end of the USEPA acceptable risk management range equivalent to 1×10^{-4} . The radiological risk estimates presented above likely are overestimated due to the conservative assumptions used in sequential decay modeling of radium-226 and radon activities calculated from the total uranium concentrations that were detected in the Site upland soils.

In order to determine the actual concentrations of radium-226 in upland soil at the Sites, a radiological site and background investigation was conducted in Fall 2014. Results from the radiological site and background investigation will be reported in 2015, and will be used to provide more realistic Site risk estimates, to determine the portion of risk attributable to background, and to establish cleanup levels (as necessary) in the Feasibility Study (FS) for the Ballard Mine.

4.0 REFERENCES

- MWH, 2011. *Ballard, Henry and Enoch Valley Mines, Remedial Investigation and Feasibility Study Work Plan*. Final. May 2011.
- MWH, 2014. *Ballard Mine Remedial Investigation and Feasibility Study Remedial Investigation Report*. Final. October 2014.
- USEPA. 1991. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors*.
- USEPA. 2014. *Preliminary Remediation Goals for Radionuclides*. http://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search Accessed November 11, 2014.

TABLES

Table A-1
Exposure Parameters Used in the Human Health Radiological Risk Assessment

Exposure Parameter		Units	Native American			Seasonal Rancher		Recreational Hunter		Recreational Camper / Hiker		
			child	adult		adult		adult		child	adult	
General												
ED = exposure duration	RME	years	6	24	a	24	a	24	a	6	24	b
Soil Exposure Pathways												
EF = exposure frequency for soil exposures	RME	days / year	270	270	a	120	a	14	a	7	7	a
IR _{soil} = soil intake rate	RME	mg/day	200	100	a	100	a	100	a	200	100	a
ET = exposure time	RME	fraction of a	2/24	2/24	a	12/24	a	1	a	1	1	a
IRA = inhalation rate	RME	m ³ /day	10	20	c	20	c	20	c	10	20	c
PEF = particulate emission factor	RME	m ³ /kg	6.62E+09		d	6.62E+09	d	6.62E+09	d	6.62E+09		d
Slab Size		m ²	1,000,000		e	1,000,000	e	1,000,000	e	1,000,000		e
Cover Layer Thickness		cm	0		f	0	f	0	f	0		f
Ingestion of Plants												
EF = exposure frequency for plant ingestion		days / year	350		a	na		na		na		
IR _{plant} = plant intake rate	RME	g/day	156	293	a	na		na		na		
MLF = mass loading factor		unitless	0.26		a	na		na		na		
Ingestion of Game												
EF = exposure frequency for game ingestion		days / year	350		a	na		350	a	na		
IR _{game} = game intake rate	RME	g/day	15.9		g	na		93.9	a	na		
MLF = mass loading factor		unitless	0.25		a	na		0.25	a	na		

Table A-1
Exposure Parameters Used in the Human Health Radiological Risk Assessment

Exposure Parameter	Units	Native American		Seasonal Rancher	Recreational Hunter	Recreational Camper / Hiker	
		child	adult	adult	adult	child	adult
CF = contaminated fraction	unitless	1	^c	na	1	^c	na
Qp_e = elk fodder intake	kg/day	2.29	^a	na	2.29	^a	na
Fp_e = fraction of year animal on site	unitless	0.025	^a	na	0.025	^a	na
Fs_e = fraction of animal's food on site	unitless	1	^a	na	1	^a	na
Qs_e = elk soil intake rate	kg/day	0.0459	^a	na	0.0459	^a	na
Qw_e = elk water intake rate	L/day	16.1	^a	na	16.1	^a	na
Ingestion of Beef							
EF = exposure frequency for beef ingestion	days / year	na		350	^a	na	na
IR _{beef} = beef intake rate							
	RME g/day	na		476	^a	na	na
MLF = mass loading factor	unitless	na		0.25	^a	na	na
Qp_c = cattle fodder intake	kg/day	na		11.77	^a	na	na
Fp_c = fraction of year animal on site	unitless	na		0.33	^a	na	na
Fs_c = fraction of animal's food on site	unitless	na		1	^a	na	na
Qs_c = cattle soil intake rate	kg/day	na		0.39	^a	na	na
Qw_c = cattle water intake rate	L/day	na		53	^a	na	na
Surface Water Direct Exposure Pathways - Incidental Ingestion and Dermal Contact							
EF = exposure frequency for surface water							
	RME days / year	122	122	^a	na	na	na
IR _{surface water} = surface water incidental intake rate							
	RME mL/day	21.6	21.6	^a	na	na	na
ET = exposure time for dermal contact							
	RME hours / day	2	2	^a	na	na	na
Notes:							
°C - degrees Celsius	mg - milligram				mL - milliliter		
cm - centimeters	L - liters				na - not applicable		
g - gram	L - liters				RME - reasonable maximum estimate		
kg - kilogram	m ³ - cubic meters						

Table A-1
Exposure Parameters Used in the Human Health Radiological Risk Assessment

Exposure Parameter	Units	Native American		Seasonal Rancher	Recreational Hunter	Recreational Camper / Hiker	
		child	adult	adult	adult	child	adult
<p>^a As derived in the Ballard Mine RI Report BRA (MWH, 2014).</p> <p>^b An recreational camper/hiker was assumed to camp in the area as a child and adult for a total of 30 years. No youth camper/hiker was evaluated because the Preliminary Remediation Goal (PRG) calculator only provides the option to evaluate a child and adult recreator.</p> <p>^c Default value from the PRG calculator.</p> <p>^d Default value from the PRG calculator for Boise, Idaho.</p> <p>^e The slab size area closest to the Ballard Mine site area of 412 acres.</p> <p>^f Zero centimeter soil cover was assumed because Site data were based on shallow soil samples.</p> <p>^g The ingestion of game rates for a Native American receptor was based on the age-adjusted rate calculated using the adult and child exposure duration and game ingestion rates presented in the Ballard Mine RI Report BRA (MWH, 2014), according to the formula: (8 g/day x 6 year + 17.9 g/day x 24 year)/30 year.</p>							

Table A-2
Tier I Ballard Mine Radiological Risk Calculation for a Native American

Radionuclide	Soil EPC ^a	Surface Water EPC ^a	Pathway-Specific Soil PRG (pCi/g) ^b										Total Soil PRG (pCi/g)	Pathway Specific Surface Water PRG (pCi/L) ^b			Total Surface Water PRG (pCi/L)	Media-Specific Cancer Risk Estimate		Total Site Cancer Risk
			Ingestion of Soil	External Exposure	Inhalation of Particulates	Ingestion of Game	Ingestion of Culturally Significant Plants	Ingestion of Surface Water	Immersion in Surface Water	Ingestion of Game	Soil	Surface Water								
													ILCR		ILCR					
mg/kg mg/L																				
Uranium, Total	87.1	0.0599	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA				
pCi/g pCi/L																				
Uranium-238	29.2	20.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA				
Radium-226	29.2	20.1	1.53	0.0650	19,400	112	0.00254	0.00244	32.9	71,200	426	30.5	1.2E-02	6.6E-07	1.2E-02					
													Cumulative ILCR:		1E-02	7E-07	1E-02			
															IDEQ Point-of-departure:		10 ⁻⁵			
															USEPA Risk Range:		10 ⁻⁶ - 10 ⁻⁴			

Notes:

^a The total uranium exposure point concentration (EPC) is based on the maximum detected concentration. Based on comments received during the development of the risk assessment work plan, measured total uranium concentrations were assumed to be representative of uranium-238 and radium-226 activity concentrations. As a result, the total uranium EPC for soil (mg/kg) was converted to uranium-238 and radium-226 EPCs (pCi/g) with a conversion factor of 0.742/2.21 pCi/g/mg/kg. The EPC for dissolved total uranium concentration in surface water is based on the maximum detected concentration; this concentration was converted from total uranium measured in in mg/L to uranium-238 and radium-226 EPCs in pCi/L with a conversion factor of 336 pCi/L/mg/L.

^b Preliminary Remediation Goals (PRGs) for Radium-226+D in soil and surface water calculated using the online PRG calculator for radionuclides.

Bold indicates ILCR estimates above USEPA's risk management range or IDEQ's point of departure

EPC - Exposure point concentration
 IDEQ - Idaho Department of Environmental Quality
 ILCR - Incremental lifetime cancer risk
 NA - Not applicable
 mg/kg - milligram per kilogram

mg/L - milligram per liter
 pCi/g - picocuries per gram
 pCi/L - picocuries per liter
 PRG - Preliminary Remediation Goal
 USEPA - United States Environmental Protection Agency

Table A-3
Tier I Ballard Mine Radiological Risk Calculation for a Seasonal Rancher

Radionuclide	Soil EPC ^a	Surface Water EPC ^a	Pathway-Specific Soil PRG (pCi/g) ^b				Total Soil PRG (pCi/g)	Surface Water PRG (pCi/L) ^c	Media-Specific Cancer Risk Estimate		Total Site Cancer Risk
			Ingestion of Soil	External Exposure	Inhalation of Particulates	Ingestion of Beef			Soil	Surface Water	
									ILCR		
	mg/kg	mg/L									
Uranium, Total	87.1	0.0599	NA	NA	NA	NA	NA	NA	NA	NA	NA
	pCi/g	pCi/L									
Uranium-238	29.2	20.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	29.2	20.1	5.15	0.0753	4,090	0.200	0.054	5.40	5.4E-04	3.7E-06	5.4E-04
Cumulative ILCR:									5E-04	4E-06	5E-04
IDEQ Point-of-departure:											10 ⁻⁵
USEPA Risk Range:											10 ⁻⁶ - 10 ⁻⁴

Notes:

^a The total uranium exposure point concentration (EPC) is based on the maximum detected concentration. Based on comments received during the development of the risk assessment work plan, measured total uranium concentrations were assumed to be representative of uranium-238 and radium-226 activity concentrations. As a result, the total uranium EPC for soil (mg/kg) was converted to uranium-238 and radium-226 EPCs (pCi/g) with a conversion factor of 0.742/2.21 pCi/g/mg/kg. The EPC for dissolved total uranium concentration in surface water is based on the maximum detected concentration; this concentration was converted from total uranium measured in in mg/L to uranium-238 and radium-226 EPCs in pCi/L with a conversion factor of 336 pCi/L/mg/L.

^b Preliminary Remediation Goals (PRGs) for Radium-226+D calculated using the online PRG calculator for radionuclides.

^c Total surface water PRGs for Radium-226+D based on uptake by beef cattle, calculated using the online PRG calculator for radionuclides.

Bold indicates ILCR estimates above USEPA's risk management range or IDEQ's point of departure

EPC - Exposure point concentration

IDEQ - Idaho Department of Environmental Quality

ILCR - Incremental lifetime cancer risk

NA - Not applicable

mg/kg - milligram per kilogram

mg/L - milligram per liter

pCi/g - picocuries per gram

pCi/L - picocuries per liter

PRG - Preliminary Remediation Goal

USEPA - United States Environmental Protection Agency

Table A-4
Tier I Ballard Mine Radiological Risk Calculation for a Recreational Hunter

Radionuclide	Soil EPC ^a	Surface Water EPC ^a	Pathway-Specific Soil PRG (pCi/g) ^b				Total Soil PRG (pCi/g)	Surface Water PRG (pCi/L) ^c	Media-Specific Cancer Risk Estimate		Total Site Cancer Risk
			Ingestion of Soil	External Exposure	Inhalation of Particulates	Ingestion of Game			Soil	Surface Water	
									ILCR		
	mg/kg	mg/L									
Uranium, Total	87.1	0.0599	NA	NA	NA	NA	NA	NA	NA	NA	NA
	pCi/g	pCi/L									
Uranium-238	29.2	20.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	29.2	20.1	44.2	0.13	35,100	23.7	0.129	90.1	2.3E-04	2.2E-07	2.3E-04
			Cumulative ILCR:						2E-04	2E-07	2E-04
IDEQ Point-of-departure:											10 ⁻⁵
USEPA Risk Range:											10 ⁻⁶ - 10 ⁻⁴

Notes:

^a The total uranium exposure point concentration (EPC) is based on the maximum detected concentration. Based on comments received during the development of the risk assessment work plan, measured total uranium concentrations were assumed to be representative of uranium-238 and radium-226 activity concentrations. As a result, the total uranium EPC for soil (mg/kg) was converted to uranium-238 and radium-226 EPCs (pCi/g) with a conversion factor of 0.742/2.21 pCi/g/mg/kg. The EPC for dissolved total uranium concentration in surface water is based on the maximum detected concentration; this concentration was converted from total uranium measured in mg/L to uranium-238 and radium-226 EPCs in pCi/L with a conversion factor of 336 pCi/L/mg/L.

^b Preliminary Remediation Goals (PRGs) for Radium-226+D calculated using the online PRG calculator for radionuclides.

^c Total surface water PRG for Radium-226+D based on uptake by game, calculated using the online PRG calculator for radionuclides.

Bold indicates ILCR estimates above USEPA's risk management range or IDEQ's point of departure

EPC - Exposure point concentration

IDEQ - Idaho Department of Environmental Quality

ILCR - Incremental lifetime cancer risk

NA - Not applicable

mg/kg - milligram per kilogram

mg/L - milligram per liter

pCi/g - picocuries per gram

pCi/L - picocuries per liter

PRG - Preliminary Remediation Goal

USEPA - United States Environmental Protection Agency

Table A-5
Tier I Ballard Mine Radiological Risk Calculation for a Recreational Camper / Hiker

Radionuclide	Soil EPC ^a	Pathway-Specific Soil PRG (pCi/g) ^b				Total Site Cancer Risk
		Ingestion of Soil	External Exposure	Inhalation of Particulates	Total Soil PRG (pCi/g)	ILCR
	mg/kg					
Uranium, Total	87.1	NA	NA	NA	NA	NA
	pCi/g					
Uranium-238	29.2	NA	NA	NA	NA	NA
Radium-226	29.2	59.0	0.209	62,500	0.208	1.4E-04
Cumulative ILCR:						1E-04
IDEQ Point-of-departure:						10⁻⁵
USEPA Risk Range:						10⁻⁶ - 10⁻⁴

Notes:

^a The total uranium exposure point concentration (EPC) is based on the maximum detected concentration. Based on comments received during the development of the risk assessment work plan, measured total uranium concentrations were assumed to be representative of uranium-238 and radium-226 activity concentrations. As a result, the total uranium EPC (mg/kg) was converted to uranium-238 and radium-226 EPCs (pCi/g) with a conversion factor of 0.742/2.21 pCi/g/mg/kg.

^b Based on the Preliminary Remediation Goals (PRGs) for Radium-226+D calculated using the online PRG calculator for radionuclides.

Bold indicates ILCR estimates above USEPA's risk management range or IDEQ's point of departure

EPC - Exposure point concentration

IDEQ - Idaho Department of Environmental Quality

ILCR - Incremental lifetime cancer risk

NA - Not applicable

mg/kg - milligram per kilogram

pCi/g - picocuries per gram

PRG - Preliminary Remediation Goal

USEPA - United States Environmental Protection Agency

APPENDIX A

P4 Response to A/T Comments, Dated January 2, 2015, on the *Draft Ballard Mine Remedial Investigation and Feasibility Study – Remedial Investigation Baseline Risk Assessment Addendum*, prepared by MWH for P4 Production LLC, dated December 2014.

General Comments

GC-1. The assumptions and calculations were reviewed and no problems were identified that would require changes. The document presents a streamlined screening approach utilizing a ratio of the maximum uranium concentration to calculated rad PRGs that are at least partly site-specific. The results are basically comparable to the Tier I residential risk estimate from the BRA. The A/T is looking forward to seeing the findings of the radiological site and background investigation which should provide greater insight to estimates site-related radiological risk and allow consideration of that risk in relation to local background risk.

P4 Response (GC-1): *Comment noted.*

Specific Comments

SC-1. **Section 3.0, Page 3-2, 2nd paragraph.** The discussion indicating that the risk estimates are likely overestimated due to the representativeness of available background data is not valid. The risk estimates for the Ballard Mine are what they are independent of background. It is the incremental risk above background that may be understated. Please revise this section to more accurately reflect the uncertainty.

P4 Response (SC-1): *Please note that only total site risk estimates, and not incremental risk estimates above background, were calculated for the Tier I human health risk assessments presented in the BRA and in the BRA Addendum. Given that incremental risk estimates were not presented in the BRA Addendum, we agree that the representativeness of the current background dataset has little impact on the uncertainty in the total risk estimates presented therein. However, P4 still believes that the total risk estimates for Ra-226 and radon presented in the BRA Addendum likely are overestimated due to the conservative assumptions used in sequential decay modeling. Therefore, P4 proposes to revise the subject statement as follows, “The radiological risk estimates presented above likely are overestimated due to the conservative assumptions used in sequential decay modeling of radium-226 and radon activities calculated from the total uranium concentrations that were detected in the Site upland soils.”*

SC-2. **Section 3.0, Page 3-2, last sentence.** Suggest revising “... in perspective during the Feasibility Study ...” to “... to provide more realistic estimates to determine the portion of the risk attributable to background levels, and to establish cleanup levels (as necessary) in the Feasibility Study ...”

P4 Response (SC-2): *Agreed. The last sentence in Section 3.0 will be revised as follows, “Results of the radiological site and background investigation will be reported in 2015, and will be used to provide more realistic Site risk estimates, to determine the portion of risk attributable to background, and to establish cleanup levels (as necessary) in the Feasibility Study (FS) for the Ballard Mine.”*

Editorial Comments

Specific Editorial Comments

1. **Acronyms and Abbreviations, page ii.** Change “A/T” to “A/Ts” for consistency with the text of the document.

P4 Response: *Agreed. Text throughout the document will be revised as requested.*

2. **Section 3.0, page 3-1, paragraph 2, line 3.** Change “(IDEQ’) s” to (IDEQ’s).”

P4 Response (SC-1): *Agreed. Text in Section 3.0 will be revised as requested.*

3. **Table A-1, page 3 of 3, e footnote.** Change “412 acre” to “412 acres.”

P4 Response (SC-1): *Agreed. Footnote “e’ in Table A-1 will be revised as requested.*